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FIXED FILM FIXED BED REACTOR – LOW COST APPROACH

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ABSTRACT

Anaerobic treatment of industrial wastewater is carried out by the use of various reactor configurations, such as fixed film fixed bed reactor, up flow anaerobic sludge blanket reactor, fluidized bed reactors, completely mixed anaerobic digester, expanded bed reactors & anaerobic filters. Usually these reactors are filled with a packing material which is of heavy weight or of high cost, such as Stone rubbles, PVC tubing, ceramic rings, Granite stones, PVC rings, RPF sheets, plastic tubes, granular activated carbon (GAC), sand reticulated foam polymers, quartz etc. Recent inventions are going on such a novel medium as a packing medium which is of very low cost, light weight as well as it gives maximum percentage removal of chemical oxygen demand (COD), Biochemical oxygen demand (BOD) and ammonium nitrate (NH_3 –N). Using fixed film fixed bed reactor, a man can optimize treatment efficiency by obtaining methane and carbon dioxide (CO_2) as useful output.

KEYWORDS: Anaerobic Reactor, Fixed Film Fixed Bed Reactor, Media, Coir Fiber, Fixed Film & Suspended Growth Process

INTRODUCTION

Anaerobic treatment of industrial wastewater is carried out by the use of various reactor configurations, such as completely mixed anaerobic digester, up flow anaerobic sludge blanket reactor, fluidized bed reactors, expanded bed reactors & anaerobic filters. Decomposition of organic and inorganic matter by micro-organisms in the absence of oxygen is termed as anaerobic digestion. Since long anaerobic digestion process has been used for domestic and industrial wastewater treatment. Anaerobic packed bed reactor was first proposed as a treatment process by Young and McCarty P. in 1969. (Mohammed Ali I. Al-Hashimi)

Different packing material were used to hold the active micro-organisms (bio mass) in pores and surface of packing in anaerobic fixed bed reactor such as Stone rubbles, PVC tubing, ceramic rings, Granite stones, PVC rings, RPF sheets, plastic tubes, granular activated carbon (GAC), sand reticulated foam polymers, quartz, coke, honey comb, corrugated sheets and pumice stone and many more. Novel packing materials such as ring lace, net plates, and fibrous materials, have also been used many times. An ideal packing material for anaerobic fixed bed reactor (attached-growth process) should have following characteristics,

- Inexpensive, (Low cost per unit volume)
- Light weight & durable,

- Low occupied volume,
- Easy to ship (Carry & handling) and install,
- Maximum specific surface area

  It should also have a large specific surface area to increase (Bio-mass attachment) bacterial growth,
- Surface Roughness
- Increased (high porosity) to prevent clogging by the increased biomass

  Increased porosity decreases overall reactor volume & ensures less clogging by increased bio-mass of filter.

Considering the above facts, inventions are going on for low cost fibrous packing material such as areca husk fiber or coconut fiber and other agro industrial waste. The fibrous material will give us large surface area per unit volume and more porosity.

FIXED-FILM VS. SUSPENDED-GROWTH PROCESS

Although the basic metabolic processes that biological systems use to remove carbon and nutrients in wastewater treatment plants (WWTPs) are the same for fixed-film (attached growth) and suspended-growth systems, there are some inherent differences that provide several advantages and some challenges for the application of fixed-film processes. Suspended-growth systems are comprised of biological flocs; but theoretically, all dissolved wastewater substrate, made of organic matter and targeted biological nutrients, is available to all cells. With fixed-growth systems, the substrates must diffuse through the biofilm layers to become available. This transport of substrate from the bulk liquid through the stagnant boundary layer, and into the biofilm through the process of diffusion, becomes a limiting factor. End products of the metabolic reactions must diffuse in the reverse direction. Fixed film processes are better than suspended growth processes in several aspects. The attached growth process is more stable than suspended growth process when the wastewater has considerable fluctuations in flow rate and concentrations.

The process of gathering of biomass (cells of micro-organisms) and retention in biomass systems are increased by attachment to a fixed medium. In the fixed film process, micro-organisms are immobilized on a support surface, forming biofilms. Substrates in the wastewater are adsorbed into the film and gradually degraded by the micro-organisms. In the suspended growth process, the micro-organisms in suspension have more intimate contact with the substrates. Limitation of mass transfer can effectively shield the micro-organisms from the shock loadings of substrates and toxins. Furthermore, even if the growth rate of biomass is reduced by adverse condition, the population of micro-organisms can still be maintained since they are physically retained in the system. Fixed media includes media that is woven into a rope or a hexagonal pattern. The fixed media is mounted on frames and remains stationary in the activated sludge basin. Free-floating media may consist of either cuboids of a sponge material or small plastic carrier elements resembling wagon wheels. The biomass grows on the surface, but is abraded from the outside surface of the media, leaving the active biomass on the inside of the wheel. (Andrew M. Jenkins) The utilization of fixed films for wastewater treatment process has been increasingly considered due to inherent advantages over suspended growth system, such as

- Simplicity of construction,
- Elimination of mechanical mixing,

- Better stability at higher loading rates, and
- Capability to withstand large toxic shock loads and organic shock loads (Lettinga, 1995).
- The reactors can recover very quickly after a period of starvation
- Reduced operating and energy costs
- Smaller reactor size (volume);
- Minimized need for settling capacity;
- Operational simplicity & high reliability; and,
- Reduced sludge.
- High biomass per reactor volume which permits higher organic loading rate,
- Short liquid detention times and

Theory of Fixed-Film Treatment

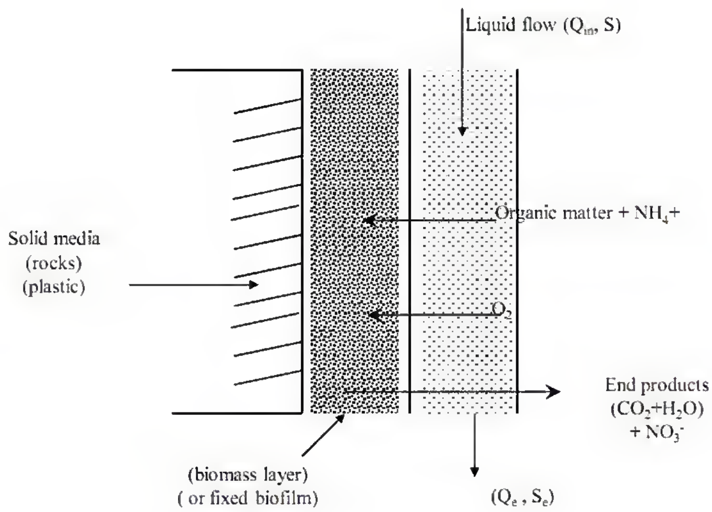

Figure 1

According to the figure shown, a biomass layer (bacteria) stick to the solid media and grow there. The liquid wastewater passes adjacent to the biomass layer forming a liquid layer. During the passage of the wastewater in the liquid layer and its contacts with the biofilm layer the organic matter, ammonia and dissolved oxygen in addition to other dissolved materials penetrate into the biomass layer by diffusion. The biochemical reactions such as organic matter oxidation, nitrification occurs inside the biofilm layer. The end products such as CO_2, H_2O, and NO_3 leave the biofilm layer back to the Liquid Layer and move out with the liquid flow to the effluent stream.

FIXED-BED REACTOR

The upflow anaerobic fixed-bed reactor (UAF-B) has been widely used as high rate anaerobic reactor for the treatment of high strength effluent. These reactors have several advantages over aerobic and conventional anaerobic reactors such as

- Rapid start-up with minimum operational problems;
- Ability to withstand shock loading without significant decrease in digestion efficiency;
- Ability to adapt intermittent feeding and rapidity of restart after lengthy shut down periods; &
- Lower hydraulic retention times.

The basic fixed-film reactor design consists of a tank filled with plastic media on which consortia of bacteria attach and grow as a slime layer or biofilm hence the name fixed-film digester. The media is fully submerged and wastewater flow can be in either the upflow or down flow mode. As the wastewater passes through the media-filled reactor, the attached and suspended anaerobic biomass converts both soluble and particulate organic matter in the wastewater to biogas, a mixture of mostly methane and carbon dioxide.

Immobilization of the bacteria as a biofilm prevents washout of slower growing cells and provides biomass retention independent of HRT. Since the bacteria are not continuously washed out along with the effluent, a substantial microbial biomass develops within the reactor. Because there are more bacteria for a given reactor volume compared to conventional suspended-growth designs, less time is needed to degrade the wastewater, allowing operation at short HRTs typically in the range of two to six days. Also, fixed-film digesters have a smaller footprint than conventional suspended-growth digesters an important factor where land availability is limited.

LITERATURE REVIEW

G. R. Shivakumaraswamy et.al.in his paper, “Domestic wastewater treatment in reactors filled with areca husk fiber and pebble bed” has studied the application of areca fiber as a fixed bed for treating domestic wastewater and to know the comparative removal efficiency of COD, BOD and NH_3 –N. One reactor filled with conventional gravel bed and other filled with areca husk fiber. In this study he continuously aerated and fed with residential wastewater having an initial average COD of 860 mg/L, BOD of 450 mg/L and NH_3-N of 70 mg/L in the bio-reactors. He used a batch mode of operation. He found that, COD, BOD and NH_3–N removal efficiency in case of a reactor filled with areca husk fiber was 89%, 89% & 76% respectively, while in case of a reactor filled with gravel bed COD, BOD and NH_3–N removal efficiency was 73.5%, 93% & 60% respectively. It clearly indicates that the performance of areca husk fiber is much superior to the gravel bed media; which indicates that fibrous material shall also prove to be useful in the anaerobic treatment of wastewater. He also found that an areca fiber is a cheapest alternative to gravel bed.

Valsa Remony Manoj et. al. in his paper, “Removal of nutrients in denitrification system using coconut coir fiber for the biological treatment of aquaculture wastewater” has also made the comparative study of coconut coir fiber and synthetic reticulated plastic media (Fujino Spirals) as a packing media in two independent upflow anaerobic packed bed column reactors for removing nitrate nitrogen at two different nitrate nitrogen loading rates (60 (NLR I) and 120 (NLR II) mg /l) from simulated aquaculture wastewater. Even he studied physico-chemical characteristics, and nature of both these media at start and end of the process. As opposite to synthetic reticulated plastic media (Fujino Spirals), coconut coir fiber gives more COD removal consistency. This gives insight that coir fiber is more efficient packing material.

At NLR 60 mg l^{-1} nitrate nitrogen concentration, the maximum COD, orthophosphate and Nitrate nitrogen removal recorded in Coconut coir was 87%, 54%, 86% and with Fujino Spirals as support, it was 82%, 55%, 80%. At NLR 120 mg l^{-1} nitrate nitrogen concentration, the maximum COD removal recorded in coconut coir was 81% (64 mg l^{-1}), 60%,

76% and the maximum COD removal recorded in FS as support was 72% (96 mg l^{-1}), 63%, 74%respectively. It clearly indicates that coconut coir is a better media in removing impurities of wastewater.

Even in the physicochemical studies, he revealed that, the energy required to break a strand of coconut coir fiber was tested in a universal testing machine. 6.35 N of energy was required to break a raw coconut coir fiber while only the energy required to break a fiber after 28 weeks of exposure to reactor conditions was 3.78 N. From these facts, he clearly mentions that, physically coconut coir fiber is much stronger (durable) considering its tensile strength after prolonged exposure of 28 weeks to wastewater. From these studies, he clearly noted that for the removal of nutrients from wastewater, in a reactor coir fiber can be as effective as synthetic media.

K V V S Kudaligama, et.al [2005] in his "Effect of Bio-brush medium: a coir fiber based biomass retainer on treatment efficiency of an anaerobic filter type reactor" paper gave the comparison of bottle brush like configuration's different specific surface area under different organic loading rates in a covered activated ditch much symbolizing anaerobic reactor. He found that, the performance of Covered Activated Ditch using the Bio-brush media made from coir fiber with 200 m^2/m^3 SSA under 1.0 COD kg/m^3 /d Organic Loading Rate gave the average COD removal of about 89% which is optimum.

K V V S Kudaligama, et.al [2007] in his paper "coir: a versatile raw material to produce stationary media for biological wastewater treatment systems" gave the different properties of coir which makes it useful as a supporting material or media for wastewater treatment. Coir is a coconut husk obtained from coconut fruit of coconut palm. It is easily available (abundant) in most of the tropical region and is cheapest material or say inexpensive. Coir contains crystalline cellulose, lignin and hemicellulose like cementing material. These materials give the give the strength to coir fiber, which increases with its age. Coarseness of coir fiber makes it useful for microbial growth; and this coarseness increases due to its irregular surface, distinct wavy outline of the edges of ultimate cell and silicified stigmata in cell wall. Its roughness can a silly adheres microbes.

He stressed the idea of using coir as effective packing material or stationary media that could be used in wastewater treatment systems at an affordable cost in fixed bed reactor. He also stressed about using different configurations of packing coir, such as loose filled fiber, fine fiber cuts, curled coir, coir twines, rubberized coir, coir bound with synthetic & natural polymers and emphasized that coir fiber arranged in bottle-brush like configuration have been most suitable configuration to achieve optimum treatment efficiency in wastewater treatment. Finally he concluded that, in developing low cost treatment facilities for different biodegradable liquid waste coir fiber base media could play an important role.

U. B. Deshannavar et.al [2012] in his paper, "High rate digestion of dairy industry effluent by upflow anaerobic fixed-bed reactor" had also designed a laboratory scale upflow anaerobic fixed-bed reactor (UAF-B) packed with polypropylene pall rings as packing media for treating dairy industry effluent. UAF-B was used to treat dairy effluent at a hydraulic retention time (HRT) of 12 hours and at different organic loading rates (OLRs). It was observed that chemical oxygen demand (COD) removal efficiency and biogas production rates increased with increase in OLR and the average COD removal efficiency of 87% and maximum biogas production of 9.8 l/d was achieved. He clearly indicates that UAF-B was feasible to treat dairy industry wastewater.

Christopher lung-wen yeong in his M Phil thesis work titled, "Removal of wastewater cod and nitrogen using fibrous packing media" studied the process in a four different bench-scale reactor; one without media. For another three reactors, he made another media with the rayon fibers were tied by a knot in the middle to form a bundle, allowing the fibers to suspend in water at radial directions. With this media in two reactors, one continuously aerated another with intermittently aerated and in last reactor the media used was prepared from rayon bundles held by two flat plastic rings 25 mm from the center, allowing the fibers to suspend only at the periphery and intermittently aerated. From these experiments, he found that intermittently aerated reactors with both the types of fibrous media were the most suitable option for the removal of COD and nitrogen.

He clearly mentions in his thesis that, fibrous packing media have the following advantages over the other type of ordinary packing media such as:

- It has got extremely high specific surface because of its biological nature. It has got more affinity to the growth of microorganisms in the reactor therefore its hydraulic retention time is reduced giving more efficiency for microbial removal and excessive wash out of microbial population does not takes place.
- Because of its biological nature of having highly porous material, it avoids clogging. Generally in fixed bed reactor, when we can treat high strength wastewater using any other synthetic media, rapid growth of biomass outstrips the sloughing rate causing clogging, resulting in serious loss of treatment efficiency; which can be avoided in fiberous media resulting in increase in treatment efficiency.
- It avoids obstruction of water due to its soft and movable nature. Thus imparts free and uniform flow of air, attached biomass and wastewater, letting generated gases to come out through the reactor, which is important factor for effective mass transfer in the biofilm wastewater treatment. Blockage and short-circuiting in the system can be avoided by the variable pores arising from these dynamic movements.
- Because of its light weight nature and its specific gravity related to that of water, it enables the treatment tank as that of fixed bed reactor is also of light weight. This becomes easier and economical for transportation, installation and handling of the reactor.

A. R. Vinod et al. in his paper, "Studies on natural fibrous materials as submerged aerated beds for wastewater treatment" also describes information made on study of naturally available fibrous materials such as sisal and Oil palm Empty fruit Bunch (OPEFB) fibers as packing media in two different bio-reactors for sewage treatment, under batch mode. He found that packing density of 50 kg/m^3 is sufficient. He observed the percentage reduction of COD (73%), BOD_5 (80%), NH_3-N (73%) and Orthophosphate (82%) with increased retention time in both reactors. Finally he concluded that, for removal of organics and nutrients, instead of using conventional medias such as plastics, open cell foam, textiles etc.; use of natural fibrous materials as a media in a fixed bed reactor for wastewater treatment equally shows promising effect.

H. H. P. Fang et al. in his paper, "Biological wastewater treatment in reactors with fibrous packing" explained about using a string of rayon fiber bundles as a media in a reactor. The bundles were evenly spaced at 60-mm intervals. One is continuously aerated and another two are intermittently aerated. He conducted various experiments on three different reactors and found that reactors when tested with synthetic wastewaters having an average COD of 958 mg/L, NH_3-N of 94 mg/L with 4-14 hr of HRT removes 95-97% of COD and nitrified up to 85% of NH_3-N with the synthetic

packing material. He also found that even after seven days of system breakdown, all reactors readily recovered their abilities to remove COD and to treat the wastewater.

With this discussion, in my research, I would like to use the Anaerobic Fixed Film Fixed Bed (AFFBR) reactor containing a bottle brush like configuration made up of combination of a coconut coir and shell media as a special media of low cost and which gives the best possible treatment for dairy (food) industry wastewater.

CONCLUSIONS

Microorganisms immobilize on a support media is the principle of anaerobic fixed film fixed bed reactors (AFFBR). Its increased capacity of microorganism retention on the support media can cause the hydraulic retention time reduced considerably. Therefore these types of reactor are widely and easily applied for the various wastewater treatments. In addition, influent variations or shock loads can easily be accustomed in anaerobic fixed film fixed bed reactors without process failure. Compared to all high rate reactors, using a coir base media the overall cost of anaerobic fixed film fixed bed reactors is much lower.

More stringent environmental laws and regulations framed by the governmental agencies have been forced to stop the untreated factory effluent discharging into natural stream or environment. Therefore for many industrialists, factory effluent has been a major problem. Keeping in view the idea of protecting the environment, finding an efficient and low cost treatment system for food industries consuming large quantities of water per day is much helpful to industrialist as well as environmentalist. Because of high cost of the wastewater treatment plant industrialists were deterred to treat the wastewater thereby polluting the atmosphere; using coir fiber which is readily available in almost all countries, the cost of anaerobic fixed film fixed bed reactor will reduce much more effectively and the nature and effectiveness of AFFBR may compel them to use this low cost process for the treatment.

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